INSTITUTE OF
PAPER CHEMISTRY
*Appleton · Wisconsin*

# STUDY OF THE USE OF WASTE PAPER IN LINERBOARD

## PHASE I. EFFECT OF TYPE OF FIBER ON MOISTURE EQUILIBRIUM CONTENT, RATE OF MOISTURE CHANGE, AND DIMENSIONAL STABILITY

Project 2695-13

Report One

A Progress Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

October 27, 1972

( FORM LETTER )

THE INSTITUTE OF PAPER CHEMISTRY
*Appleton, Wisconsin 54911*
*Phone 414/734-9251*

January 3, 1973

Project 2695-13

Mr. T. J. Gross
Technical Director
Fourdrinier Kraft Board Institute, Inc.
Suite 810, 1605 Main Street
Sarasota, Florida 33577

Dear Mr. Gross:

Enclosed are copies of two reports concerned with waste paper utilization. One is entitled "Study of the Use of Waste Paper in Linerboard; Phase I. Effect of Type of Fiber on Moisture Equilibrium Content, Rate of Moisture Change, and Dimensional Stability." Report One, Project 2695-13. The other report is entitled "Study of the Use of Waste Paper in Kraft Linerboard; Phase II. Effect of Adding Secondary Stock on the Properties of Kraft Linerboard." Report Two, Project 2695-13.

A third report concerned with Phase III will be ready for distribution shortly.

The results obtained in Phase 1 indicate the following:

1. There appears to be no marked difference in the moisture content of handsheets made from furnishes of virgin kraft pulp, repulped kraft paper, and secondary paper stock such as corrugated container stock.

2. The rate of moisture adsorption and desorption appears to be fairly independent of the type of fiber.

3. The hygroexpansivity tests indicate that at the same degree of refining, in terms of freeness, sheets made from corrugated container stock have no greater dimensional instability than corresponding sheets made with virgin fibers.

4. The lower the freeness of the furnish the greater the dimensional instability. Therefore, in considering the practical case of a virgin kraft sheet made at a relatively high freeness level with a reclaimed fiber sheet refined to a relatively low freeness, it would be expected that the reclaimed sheet would be less stable dimensionally than the sheet made with the higher freeness stock - in this case, kraft pulp.

The results obtained in Phase II wherein different percentages of waste were added to a kraft furnish, show that in general the higher the percentage of waste, the lower the bursting strength. The greater the degree of refining of the paper stock, the lower the loss in bursting strength, with increase in percentage of paper stock for the handsheets made with furnishes containing kraft pulp at 590-ml. freeness. Except in a few cases, the other properties tended to either decrease or remain essentially unchanged with increase in percentage of paper stock. The same general trend was observed for the two paper stock used--corrugated containers and double-lined kraft corrugated cuttings.

If there are any questions regarding the above reports, please let us know.

Yours very truly,

RCMcKee

R. C. McKee
Chairman
Container Section

RCM/mjm
Enclosure
Same mailing to A. R. Boren

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## SUMMARY


A study was undertaken to compare the effect of the type of fiber on the rate of moisture change, equilibrium moisture content, and dimensional stability when exposed to a relative humidity cycle of 12 → 50 → 90 → 50 → 12% R.H. For this study, handsheets made from virgin kraft pulp, repulped kraft paper, and corrugated container stock were compared in terms of: (a) equilibrium moisture content, (b) rate of moisture change, and (c) hygroexpansivity.

The results obtained indicate the following:

1. There appears to be no marked difference in the moisture content of handsheets made from furnishes of virgin kraft pulp, repulped kraft paper, and secondary paper stock such as corrugated container stock.

2. The rate of moisture adsorption and desorption appears to be fairly independent of the type of fiber.

3. The hygroexpansivity tests indicate that at the same degree of refining, in terms of freeness, sheets made from corrugated container stock have no greater dimensional instability than corresponding sheets made with virgin fibers.

4. The lower the freeness of the furnish the greater the dimensional instability. Therefore, in considering the practical case of a

virgin kraft sheet made at a relatively high freeness level with a reclaimed fiber sheet refined to a relatively low freeness, it would be expected that the reclaimed sheet would be less stable dimensionally than the sheet made with the higher freeness stock — in this case, kraft pulp.

## INTRODUCTION

Project 2695-13 was initiated by the Fourdrinier Kraft Board Institute as a three-phase study to develop technology related to waste paper utilization. The three phases are:

1. The effect of the type of fiber on the rate of moisture change, equilibrium moisture content, and dimensional stability.

2. The effect of varying amounts of secondary stock on the strength properties of linerboard.

3. The effect of blending repeatedly repulped or recycled secondary fibers on the strength properties of linerboard.

The above phases were explored by means of handsheet studies. That is, handsheets were made of the appropriate furnishes and examined in terms of moisture behavior and/or strength properties. This report is concerned with Phase I. Phases II and III will be the subject of subsequent reports.

The rate of moisture adsorption, equilibrium moisture content, and dimensional stability are important characteristics of paperboard. It is not uncommon for some people to associate a sheet made with a waste paper with a higher rate of moisture adsorption, equilibrium moisture content, and dimensional instability than a corresponding sheet made with virgin kraft fibers. In theory, however, paperboard made with waste paper such as double-lined corrugated waste should exhibit less moisture adsorption and less dimensional instability than a sheet made with virgin fibers when both are refined to the same freeness level. In order to compare the effect of the type of fiber on "moisture behavior," handsheets were made with three different types of fibers under a number of different conditions. The three types of fibers used were:

1. Virgin kraft fibers,
2. Repulped virgin kraft fibers, and
3. Corrugated container paper stock.

The virgin kraft fibers were unbleached kraft pulp of a commercial grade. The repulped kraft fibers were obtained by refining the virgin kraft to approximately 700-ml. Canadian Standard freeness, making into handsheets which were subsequently heat dried and then using these handsheets as the repulped fibers. The waste paper used in this phase of the study consisted of a grade designated as corrugated container (No. 10) by the Paper Stock Institute. Inasmuch as the quality of paper stocks may vary markedly depending on the geographic location, four sample lots of this grade were obtained from dealers or paperboard mills representing West Coast, North Central Region, Eastern, and Southeast areas of the country. The four lots were fiberized by combining equal parts by weight of each lot in a small hydrapulper at 2% consistency. The hydrapulper was used merely to fiberize the resulting mixture. This fiber mixture was used throughout Phase I and also in Phase II.

Originally, the refining program had been designed to compare the three different fibers at two levels of freeness: at 300 ml. and at the freeness level of the slushed corrugated container stock. The slushed corrugated container stock had a freeness of 640 ml. Due to an error, the virgin kraft was refined to 700 and 350 ? ~~300~~ ml. instead of 640 and 300 ml. In addition, the handsheets made with virgin kraft pulp refined to 350 ~~300~~-ml. freeness were used for repulping instead of the handsheets made with the 700-ml. freeness virgin kraft pulp. The freeness levels of the six handsheet samples used in Phase I are shown in Table I.

TABLE I

HANDSHEET SAMPLES

| Sample No. | Type Furnish | Freeness Level, ml. |
|---|---|---|
| 1-X | Corrugated container stock | 640 |
| 1 | Virgin kraft pulp | 700 |
| 2 | Virgin kraft pulp | 300 |
| 3 | Repulped kraft handsheets | 335 |
| 4 | Repulped kraft handsheets | 300 |
| 2-X | Corrugated container stock | 305 |

The six different fiber furnishes listed in Table I were made into handsheets on the British sheet mold. Each handsheet sample was evaluated for rate of moisture change, equilibrium moisture content, and dimension stability (in terms of hygroexpansivity). Prior to evaluation, all the handsheets were conditioned in an atmosphere maintained at approximately 12% R.H. at 73°F. Rate of moisture change and equilibrium moisture content (airdry basis) were determined in a variable humdity room wherein the humidity was cycled approximately as follows: 12 → 50 → 90 → 50 → 12% R.H. The hygroexpansivity tests were conducted in a Neenah Hygroexpansivity tester using saturated salt solutions to control the relative humidity at approximately the levels described above for the variable humdity room. The actual relative humdity levels attained were 11.1, 48.6, 92.9, 48.6, and 11.1% R.H. All the samples were tested in the Neenah Hygroexpansivity tester at the same time; thus, all were exposed to the same atmospheric conditions.

## DISCUSSION OF RESULTS

### MOISTURE EQUILIBRIUM LEVEL AND RATE OF CHANGE

The equilibrium moisture content of the six different samples are given in Table II.

It may be seen from the results listed in Table II and illustrated in Fig. 1 and 2 that the differences in equilibrium moisture content were very small at the various humidity levels. Differences of these magnitudes could be expected between different samples of the same grade. Further, there appears to be no marked difference between the handsheets made with virgin kraft fibers refined to 700-ml. freeness and the handsheets made with waste paper — i.e., corrugated container paper stock — refined to 640 ml. When the results are considered for the handsheets made with furnishes refined to 300-ml. freeness, the virgin kraft handsheet samples exhibited higher equilibrium moisture contents than the corresponding samples made with waste paper or repulped kraft; however, the differences are not believed to be significant when the results at the higher freeness levels — i.e., 640-700 ml. — are compared with the results at 300-ml. freeness. Normally, it is considered that the more a fiber is refined the higher will be the equilibrium moisture content although the increase is usually very small.

The results of the rate of moisture change in cycling 12 → 50 → 90 → 50 → 12% R.H. are listed in Tables III-VI and illustrated in Fig. 3-6.

It may be seen from the results plotted in Fig. 3-6 that, in general, the rate of moisture adsorption or desorption was about the same, in a practical sense, for all six samples. The greatest difference appears in the early period of the adsorption taking place where the samples conditioned at 12% R.H. were

TABLE II

MOISTURE EQUILIBRIUM CONTENT
(Airdry basis)

| Sample Number | Type Furnish | Freeness, ml. | Moisture Equilibrium Content, %: Relative Humidity Level, % | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 12 | Diff.,%[a] | 50 | Diff.,%[a] | 90 | Diff.,%[a] | 50 | Diff.,%[a] | 12 | Diff.,%[a] |
| 1-X | Corrugated container stock | 640 | 3.7 | — | 8.0 | — | 19.1 | — | 8.7 | — | 3.7 | — |
| 1 | Virgin kraft pulp | 700 | 3.7 | 0.0 | 7.8 | -2.5 | 18.9 | 1.0 | 8.4 | 3.4 | 3.6 | 2.7 |
| 2 | Virgin kraft pulp | 300 | 4.1 | 10.8 | 8.2 | 2.5 | 19.5 | 2.1 | 8.9 | 2.3 | 4.1 | 10.8 |
| 3 | Repulped kraft handsheet from 2 | 335 | 3.7 | 0.0 | 7.8 | -2.5 | 19.3 | 1.0 | 8.5 | 2.3 | 3.7 | 0.0 |
| 4 | Repulped kraft handsheet from 2 | 300 | 3.9 | 5.4 | 7.8 | -2.5 | 19.1 | 0.0 | 8.5 | 2.3 | 3.9 | 5.4 |
| 2-X | Corrugated container stock | 305 | 3.7 | 0.0 | 7.9 | -1.3 | 18.9 | 1.0 | 8.7 | 0.0 | 3.7 | 0.0 |

[a]Corrugated stock at 640-ml. freeness used as reference.

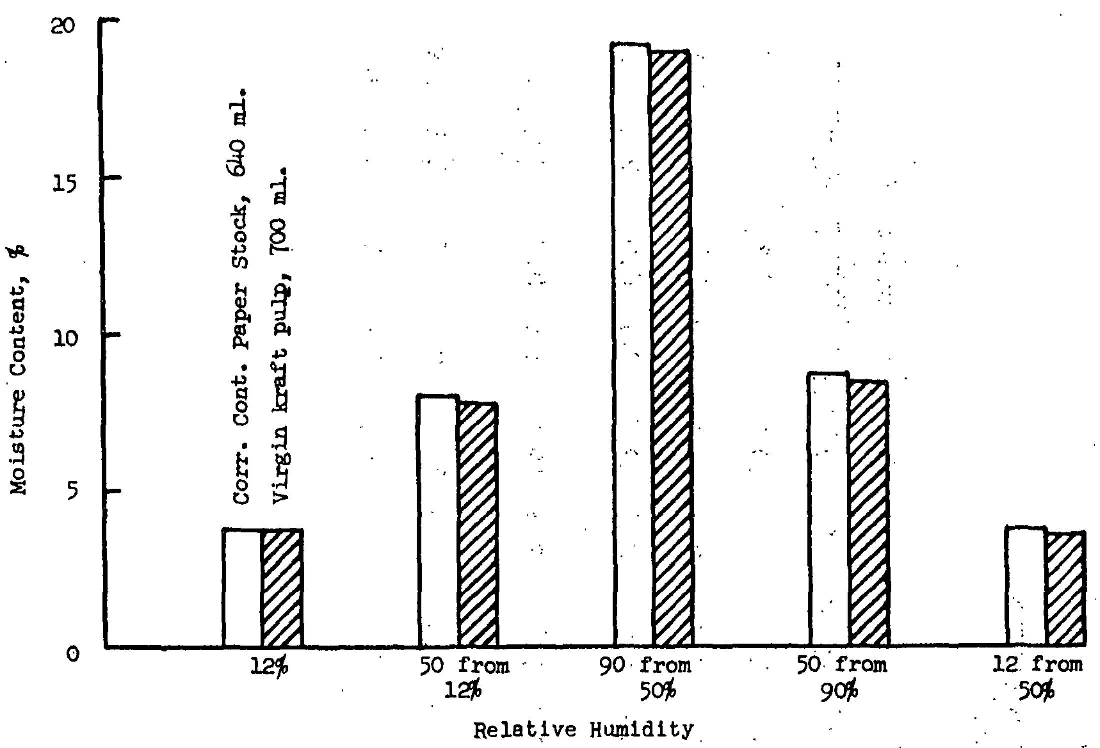


Figure 1. Comparison of Moisture Equilibrium Content of Handsheet

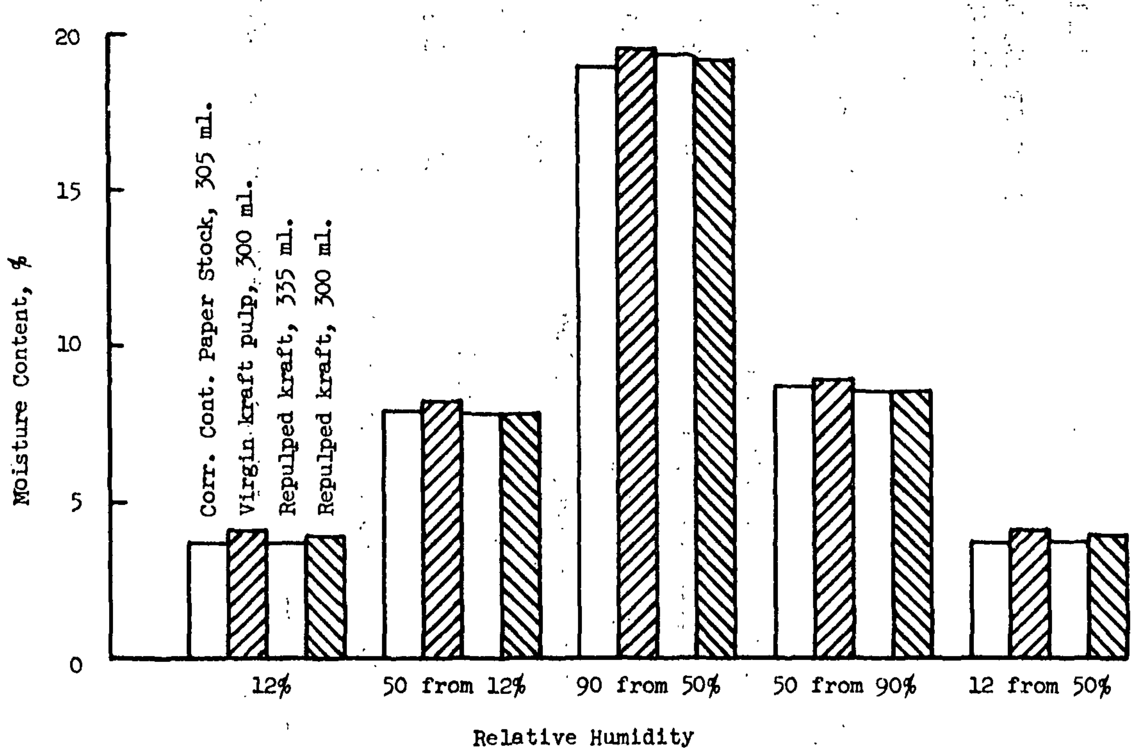


Figure 2. Comparison of Moisture Equilibrium Content of Handsheet

TABLE III

RATE OF MOISTURE ABSORPTION BETWEEN 12 AND 50% R.H.

| Exposure Time, min. | Percent of Total Change | | | | | |
|---|---|---|---|---|---|---|
| | Sample 1-X | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 2-X |
| 0.5 | 25.8 | 21.8 | 13.5 | 16.9 | 19.7 | 21.4 |
| 1 | 37.8 | 27.4 | 18.5 | 24.6 | 23.7 | 28.2 |
| 2 | 50.0 | 43.8 | 29.1 | 39.0 | 37.7 | 40.6 |
| 4 | 70.1 | 65.6 | 49.2 | 64.0 | 54.7 | 59.5 |
| 8 | 85.8 | 87.6 | 71.5 | 84.0 | 76.4 | 79.9 |
| 16 | 94.5 | 97.2 | 91.1 | 94.9 | 91.9 | 93.0 |
| 32 | 96.6 | 99.3 | 96.9 | 98.6 | 97.7 | 96.1 |
| 64 | 98.4 | 99.4 | 97.7 | 99.2 | 99.0 | 98.2 |
| 128 | 99.1 | 99.3 | 98.5 | 99.6 | 99.6 | 99.0 |
| 256 | 99.7 | 99.3 | 99.6 | 99.8 | 99.9 | 99.9 |
| 512 | 99.8 | 99.9 | 99.8 | 99.9 | 99.9 | 100.0 |

TABLE IV

RATE OF MOISTURE ABSORPTION BETWEEN 50 AND 90% R.H.

| Exposure Time, min. | Percent of Total Change | | | | | |
|---|---|---|---|---|---|---|
| | Sample 1-X | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 2-X |
| 0.5 | 9.4 | 8.4 | 8.5 | 8.6 | 9.2 | 8.9 |
| 1 | 13.6 | 11.9 | 11.1 | 11.1 | 11.7 | 11.6 |
| 2 | 18.4 | 18.0 | 16.1 | 17.1 | 17.2 | 17.1 |
| 4 | 28.6 | 25.5 | 25.4 | 26.9 | 26.7 | 28.2 |
| 8 | 41.4 | 38.6 | 37.6 | 39.6 | 39.6 | 40.7 |
| 16 | 54.4 | 51.0 | 49.9 | 52.2 | 52.4 | 56.3 |
| 32 | 67.4 | 58.9 | 60.5 | 63.5 | 65.4 | 69.2 |
| 64 | 74.8 | 72.5 | 73.2 | 71.6 | 74.6 | 76.2 |
| 128 | 80.9 | 78.2 | 78.4 | 79.1 | 79.9 | 82.8 |
| 256 | 91.9 | 92.1 | 91.4 | 91.8 | 91.9 | 92.3 |
| 512 | 94.6 | 94.7 | 93.9 | 94.5 | 94.2 | 95.8 |

TABLE V

RATE OF MOISTURE DESORPTION BETWEEN 90 AND 50% R.H.

| Exposure Time, min. | Percent of Total Change | | | | | |
|---|---|---|---|---|---|---|
| | Sample 1-X | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 2-X |
| 0.5 | 30.9 | 34.2 | 34.2 | 30.8 | 31.2 | 30.3 |
| 1 | 35.3 | 37.3 | 41.1 | 33.8 | 34.5 | 35.1 |
| 2 | 46.1 | 44.8 | 56.2 | 43.8 | 47.1 | 47.3 |
| 4 | 60.2 | 63.2 | 66.0 | 59.1 | 60.9 | 59.6 |
| 8 | 76.0 | 80.6 | 80.9 | 77.1 | 78.3 | 76.3 |
| 16 | 90.6 | 92.8 | 92.6 | 91.8 | 90.6 | 90.4 |
| 32 | 97.1 | 98.3 | 98.4 | 98.2 | 97.5 | 96.5 |
| 64 | 97.5 | 98.9 | 99.3 | 98.7 | 98.3 | 97.1 |
| 128 | 99.2 | 99.3 | 99.9 | 99.6 | 99.5 | 98.9 |
| 256 | 99.4 | 99.5 | 100.0 | 99.6 | 99.7 | 99.1 |
| 512 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

TABLE VI

RATE OF MOISTURE CHANGE FROM 50 TO 12% R.H.

| Exposure Time, min. | Percent of Total Change | | | | | |
|---|---|---|---|---|---|---|
| | Sample 1-X | Sample 1 | Sample 2 | Sample 3 | Sample 4 | Sample 2-X |
| 0.5 | 27.1 | 29.9 | 27.9 | 27.5 | 28.6 | 27.6 |
| 1 | 32.4 | 32.4 | 31.3 | 30.4 | 33.2 | 32.6 |
| 2 | 43.6 | 45.0 | 40.6 | 42.0 | 42.9 | 43.0 |
| 4 | 59.7 | 59.1 | 52.1 | 57.7 | 56.3 | 58.6 |
| 8 | 75.1 | 75.6 | 65.9 | 73.4 | 69.5 | 70.7 |
| 16 | 86.3 | 86.8 | 79.0 | 84.4 | 81.6 | 83.5 |
| 32 | 90.3 | 90.6 | 87.6 | 89.9 | 88.3 | 88.6 |
| 64 | 90.3 | 91.6 | 88.6 | 90.8 | 88.4 | 89.1 |
| 128 | 91.6 | 92.3 | 91.2 | 91.4 | 90.9 | 91.4 |
| 256 | 93.3 | 92.6 | 92.4 | 92.9 | 92.8 | 92.9 |
| 512 | 93.7 | 94.0 | 94.0 | 94.3 | 93.8 | 94.2 |

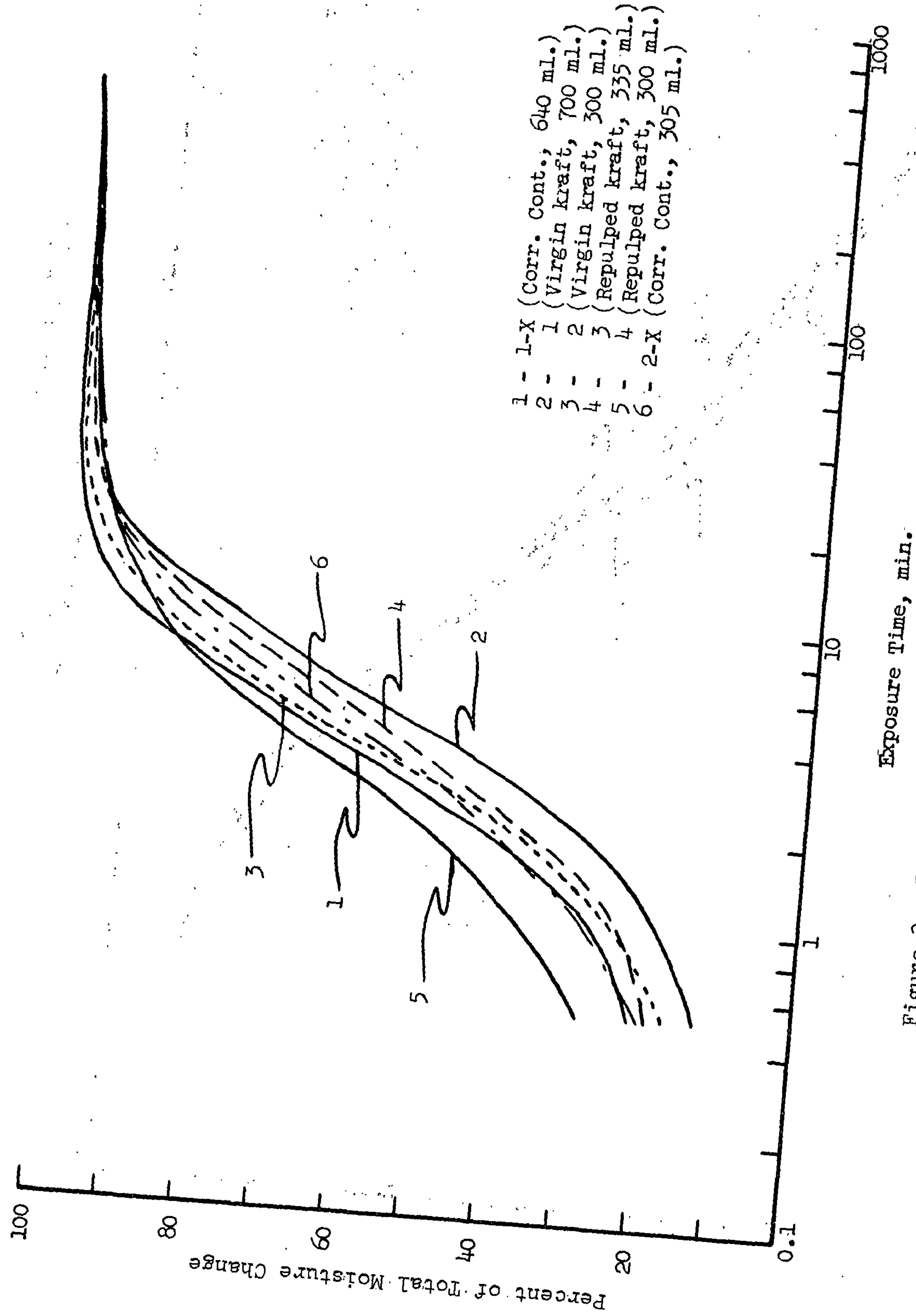


Figure 3. Rate of Moisture Adsorption (12 to 50% R.H.)

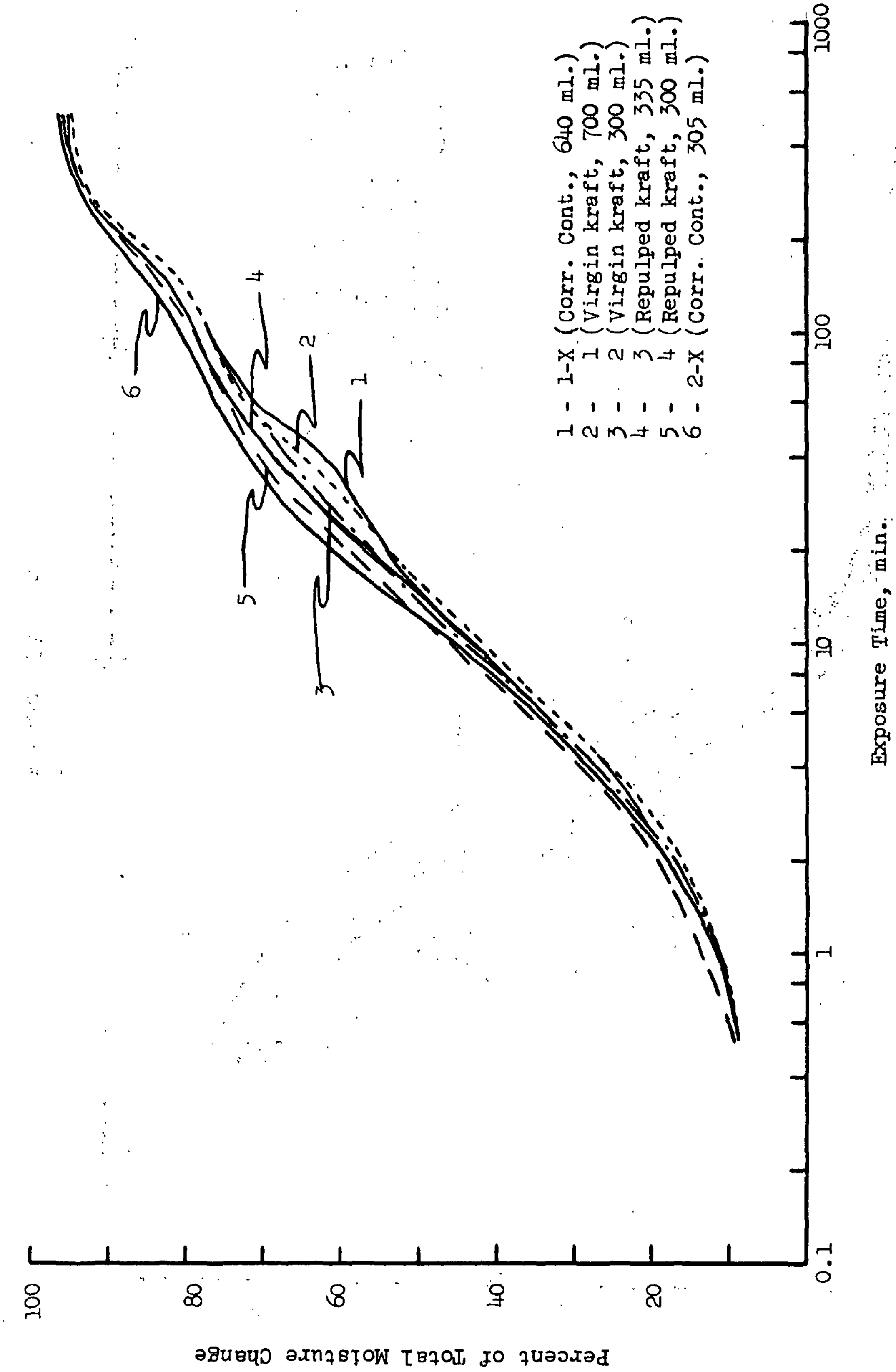


Figure 4. Rate of Moisture Adsorption (50 to 90% R.H.)

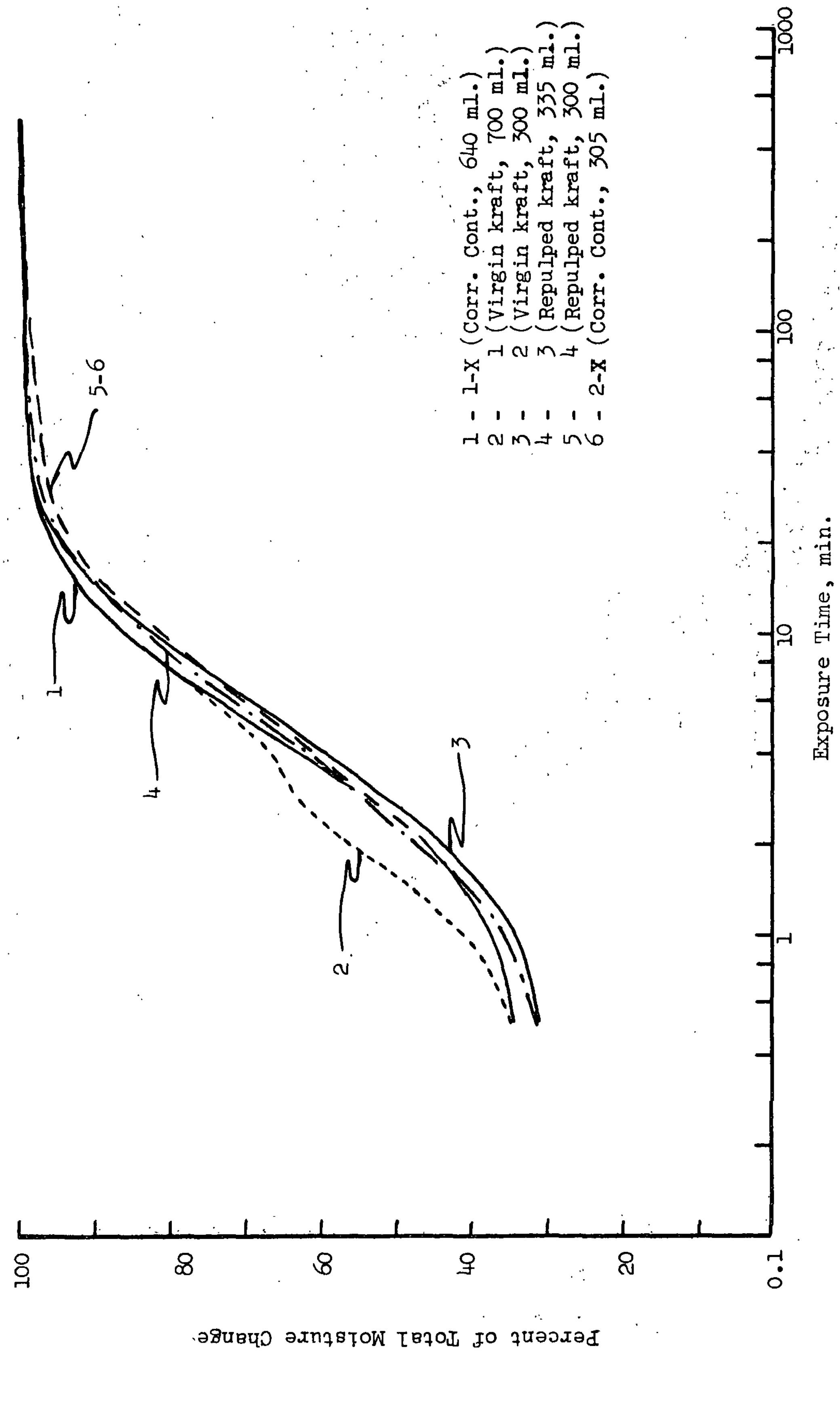


Figure 5. Rate of Moisture Desorption (90 to 50% R.H.)

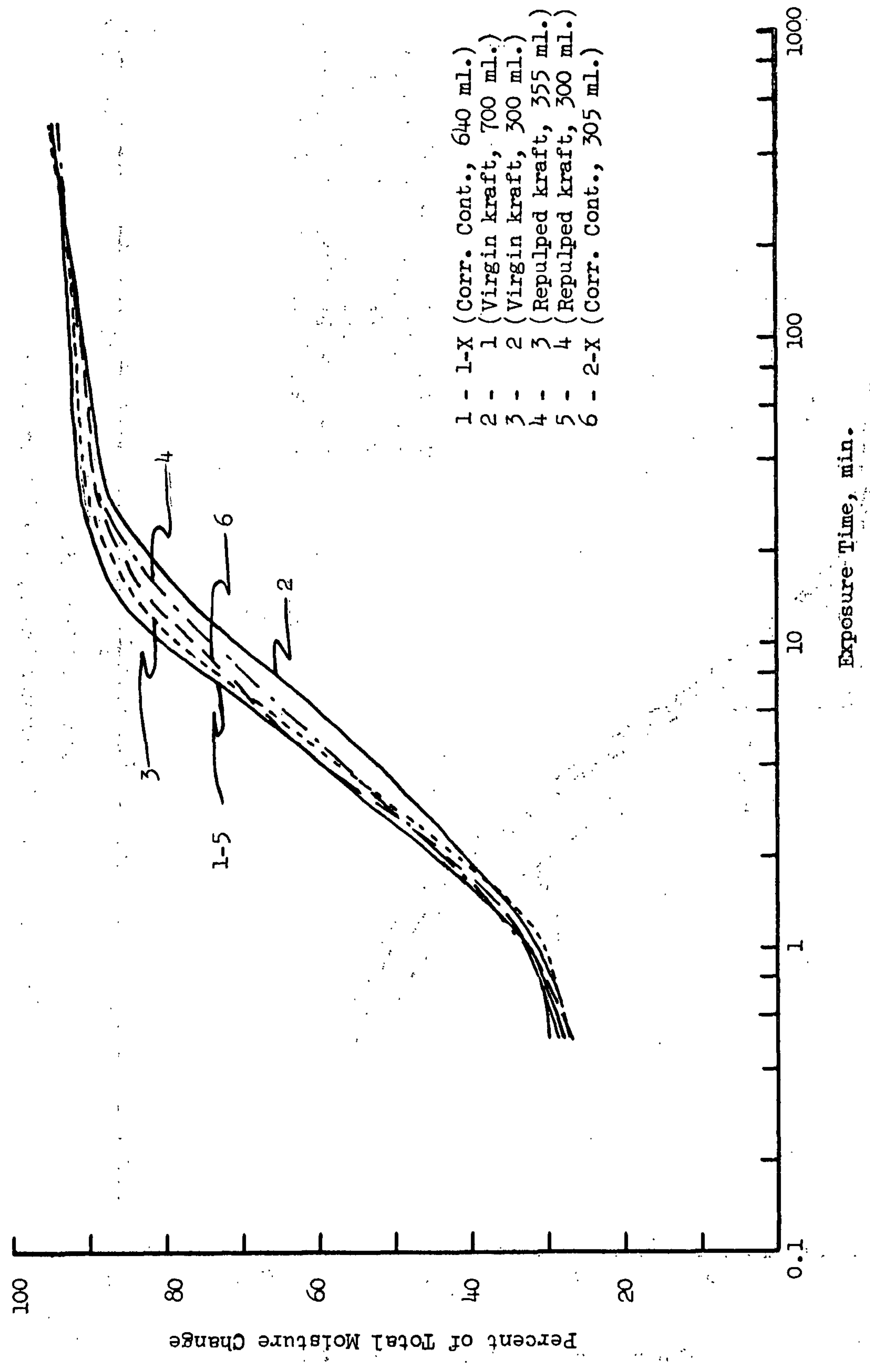


Figure 6. Rate of Moisture Desorption (50 to 12% R.H.)

exposed to the 50% R.H. atmosphere. For example, Samples 1-X and 1 exhibited slightly higher moisture content changes than the other samples at the 0.5, 2.4, and 8-minute exposure periods. At the 32-minute exposure period, all samples had undergone more than 96% of the total moisture change. Although the differences exhibited at the 32-minute period are probably not significant, Samples 1 and 3 exhibited the highest percent moisture change and Samples 1-X and 2-X the lowest. At the 256-minute exposure, all six samples exhibited percent of total change of better than 99%.

HYGROEXPANSIVITY (DIMENSIONAL STABILITY) ~~AND RATE OF CHANGE IN LENGTH~~

As previously mentioned, the dimensional stability of the six samples used in this study was evaluated in terms of the expansion and contraction when cycled 12 → 50 → 90 → 50 → 12% R.H. The hygroexpansivity results expressed in terms of the percent change in length at each relative humidity change as well as the percent net change in length for the whole humidity cycle, are given in Table VII. In Table VII the results are tabulated to show the total length increase in going from 12% R.H. to 90% R.H. This is equal to the sum of the changes from (a) 12 to 50% R.H., and (b) 50 to 90% R.H. Similarly, the total contraction in length from 90 to 12% R.H. is also shown together with the net difference in percent length change. This is equal to the total length increase from 12 to 90% R.H. minus the total length decrease from 90 to 12% R.H. Since the latter is larger numerically than the former, it means that the net result of exposure to the relative humidity cycle 12 → 50 → 90 → 50 → 12% R.H. is a decrease in length. This is due to the relaxation of the dried-in strains induced when the sheet was made initially.

TABLE VII

HYGROEXPANSIVITY RESULTS

| Sample Number | Type Furnish | Freeness, ml. | Hygroexpansivity-Length Change, % 12-50% R.H. | 50-90% R.H. | Total Change 12-90% R.H. | 90-50% R.H. | 50-12% R.H. | Total Change 90-12% R.H. | Net Change Total Cycle |
|---|---|---|---|---|---|---|---|---|---|
| 1-X | Corrugated container stock | 640 | 0.254 | 0.288 | 0.542 | -0.471 | -0.332 | -0.803 | -0.261 |
| 1 | Virgin kraft pulp | 700 | 0.224 | 0.240 | 0.464 | -0.438 | -0.314 | -0.752 | -0.288 |
| 2 | Virgin kraft pulp | 300 | 0.282 | 0.281 | 0.563 | -0.577 | -0.410 | -0.987 | -0.424 |
| 3 | Repulped kraft handsheet from 2 | 335 | 0.267 | 0.283 | 0.550 | -0.508 | -0.360 | -0.868 | -0.318 |
| 4 | Repulped kraft handsheet from 2 | 300 | 0.270 | 0.284 | 0.554 | -0.561 | -0.384 | -0.945 | -0.391 |
| 2-X | Corrugated container stock | 305 | 0.281 | 0.297 | 0.578 | -0.545 | -0.384 | -0.929 | -0.351 |

It may be seen in Table VII and Fig. 7 that Samples 1 (virgin kraft at 700 ml.) and 1-X (corrugated container stock at 640 ml.) exhibited less change in length when going from 12 to approximately 90% R.H. than did the other samples. Further, the virgin kraft (Sample 1) exhibited less change (expansion) in length than did the corrugated container stock (Sample 1-X). The same general behavior may be seen for the change in length on decreasing the relative humidity from 90 to 12% R.H. (Fig. 8). When the net change in length due to the exposure to one complete relative humidity cycle is considered, it may be seen that Samples 1 and 1-X exhibited less change in length than the samples refined to the 300-ml. freeness level. In addition, the corrugated container stock (Sample 1-X) exhibited less net change in length than the virgin kraft (Sample 1). The corresponding results of the samples made from stock refined to 300 ml. show that the virgin kraft sheet exhibited a greater net change in length than the repulped or corrugated container stock samples (Fig. 9). These results indicate that the hygroexpansivity of sheets made from reclaimed fiber have no significantly greater dimensional instability than sheets made from virgin kraft at the same degree of refining.

In practice, the stock used in the manufacture of linerboard from waste paper is refined to a much lower freeness than kraft linerboard stock in order to develop the necessary level of strength; although the stock used in Sample 1 (virgin kraft at 700-ml. freeness) is considerably higher in freeness than the average kraft linerboard furnish, a comparison of Samples 1 (virgin kraft at 700 ml.) and 2-X (corrugated container stock) may serve to illustrate the trend to be expected. When the above comparison is considered, it may be seen that the corrugated container stock sample (Sample 2-X) exhibited a greater expansion in going from 12 to 90% R.H., a greater contraction in going from 90 to 12% R.H., and a greater net change in length for one cycle than did the

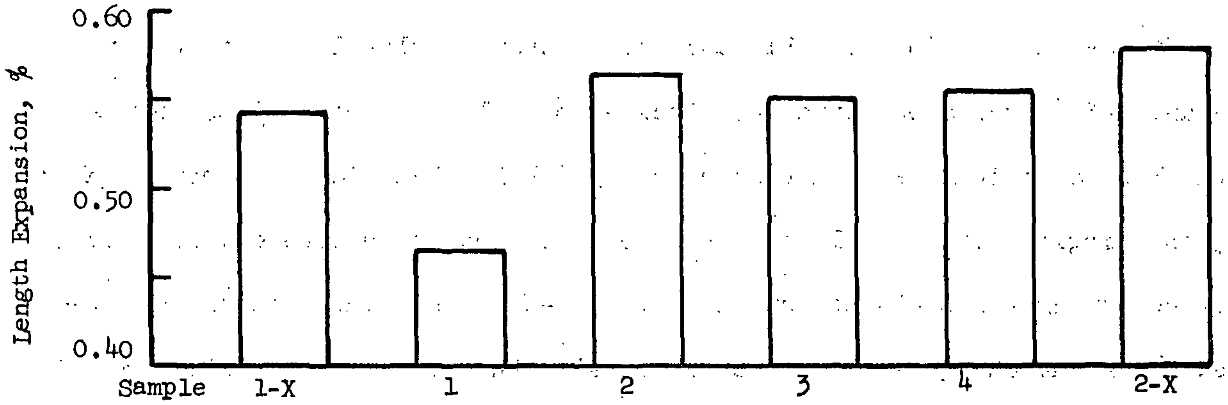


Figure 7. Hygroexpansivity Results (12-90% R.H.)

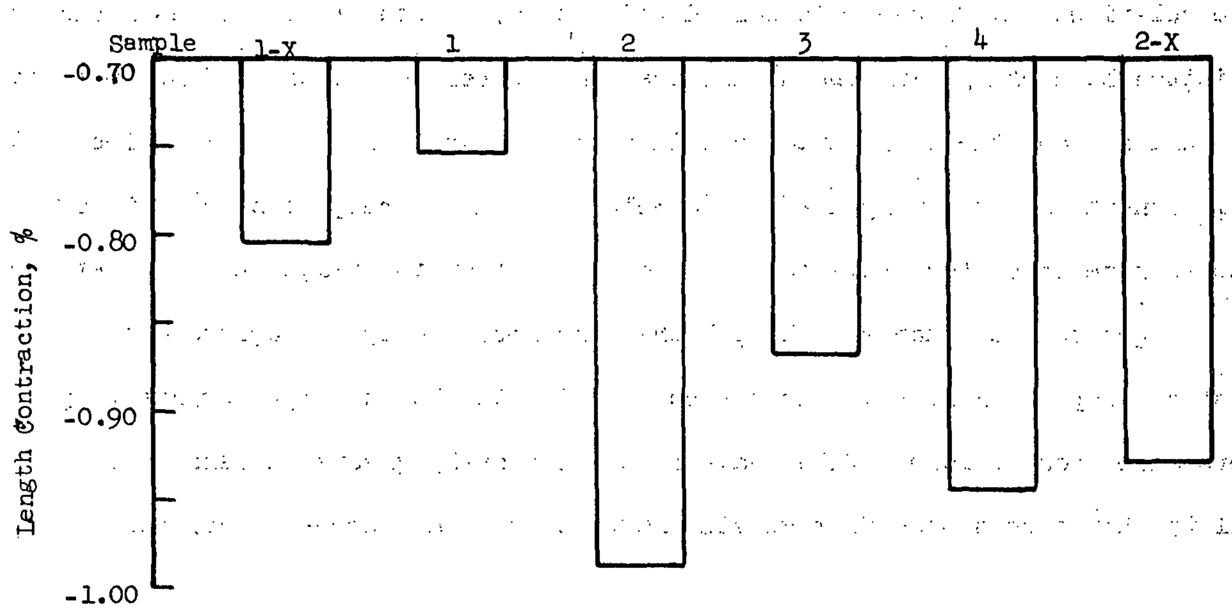


Figure 8. Hygroexpansivity Results (90-12% R.H.)

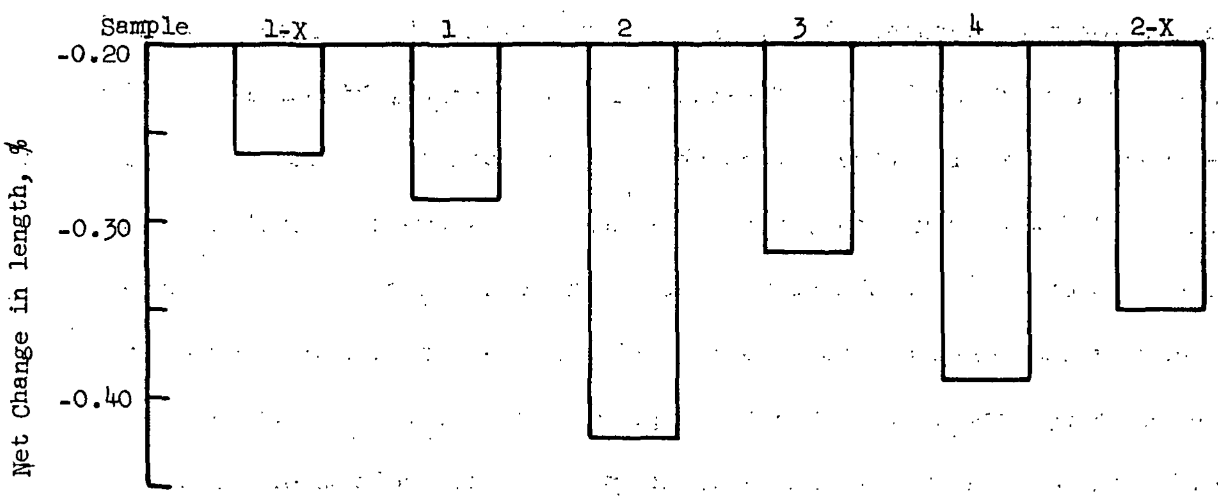


Figure 9. Hygroexpansivity Results for One Humidity Cycle (12 → 50 → 90 → 50 → 12% R.H.)

virgin sample (Sample 1). Under these conditions it may be expected that the dimensional stability of the virgin kraft sheet will be better than a corresponding sheet made from more highly refined reclaimed fibers.

It should be emphasized that the results obtained in this study are based on handsheet performance and therefore are not influenced by the machine effects associated with commercial linerboard.